Teacher's Edition of the Student Discovery Journal
How Plants Work: A Guide to Being Green

(Insert botanical-themed graphics)

Welcome to the United States Botanic Garden's *How Plants Work* Exhibit! This permanent exhibit in the East Gallery reveals the secrets of how plants – seemingly sedentary organisms – manage to survive in every corner of the planet. There are larger-than-life models, interactive features, and a host of live examples that help students, and their adult mentors, understand and appreciate their green partners and man's dependence upon them for survival.

While engaged in the *How Plants Work* Exhibit, students will explore 5 'Big Ideas' relating to plants. Through their investigations, students will discover the intriguing life, structural design, adaptability and resourcefulness of plants.

The 'Big Ideas' for the *How Plants Work* Exhibit are:

1) **Are Plants Like Us? –** Explore the phenomenal things plants can do and how thoroughly man depends upon them. Use the huge family tree "map" to trace familiar plants back to their ancestral roots.
2) **A Puzzle of Plant Parts** – A colorful and impressive plant sculpture (dubbed *Scarlet magnifica*) shows off its stunning oversized parts. Real plants and panels reveal that plant parts take many forms as a result of being adapted to unique environments.
3) **The Green Machine** – This section features another larger-than-life plant sculpture (named *Electra botanica*), complete with interactive light displays. These displays demonstrate the industrious and busy life of a plant, representing what happens during photosynthesis and beyond.
4) **Surviving Against the Odds** – At this station students come to appreciate the incredible variety of ways in which plants meet their daily challenges (e.g. battling predators, surviving drought, finding enough light, etc.).
5) **Plant Multiplication** – This area explores reproductive cycles for four plant groups: ferns (vascular, spore producing plants), mosses (non-vascular, spore producing plants), gymnosperms (cone bearing plants), and angiosperms (flowering plants).

As students investigate the 5 'Big Idea' topics in the *How Plants* Work Exhibit, they will have the opportunity to venture into the Conservatory. While trekking though the different habitats, students will discover living examples of how plants work and see each 'Big Idea' in action.

The intent of the *How Plants Work* Exhibit and its corresponding curriculum is not to create a list of facts and figures. Instead, the intent is to challenge students to explore, think, and come up with their own questions and conclusions about how plants work and the various ways plants impact human life.

How to Use This Guide:
Each 'Big Idea' Exhibit area is explored in this guide by:

- Introducing the topic by having students explore the related *How Plants Work* Exhibit area.
- Presenting activities that enable students to explore the 'Big Idea' topic out in the Conservatory.
- Providing students with a means for more detailed exploration of each 'Big Idea' topic via a "Dig Deeper" section.
- Concluding with remarks and discussion points to help students summarize and reflect on their 'Big Idea' related learning experience.

Guidelines for Managing Your Class Visit:

- Depending on your use of the Journal, allow anywhere from 1 to 3 hours to visit.
- Divide students into pairs or small groups. Assign one chaperone to each pair or small group.
- Provide the class with an introduction into each of the "Big Idea" Sections via the *How Plants Work* Exhibit Introductory Lesson.
- Jigsaw the Student Discovery Journal and assign each pair or group a specific 'Big Idea' activity to be shared with the rest of the class upon returning to school.

National Standards
The following standards are met via the completion of the Student Discovery Journal:

Journal Activity	**National Standards**
Are Plants Like Us?	NS.K-4.1 – SCIENCE AS INQUIRY NS.5-8.1 – SCIENCE AS INQUIRY NS.K-4.3 – LIFE SCIENCE NS.5-8.3 – LIFE SCIENCE
A Puzzle of Plant Parts	NS.K-4.1 – SCIENCE AS INQUIRY NS.5-8.1 – SCIENCE AS INQUIRY NS.K-4.3 – LIFE SCIENCE NS.5-8.3 – LIFE SCIENCE
The Green Machine	NS.K-4.1 – SCIENCE AS INQUIRY NS.5-8.1 – SCIENCE AS INQUIRY NS.K-4.3 – LIFE SCIENCE NS.5-8.3 – LIFE SCIENCE
Surviving Against the Odds	NS.K-4.1 – SCIENCE AS INQUIRY NS.5-8.1 – SCIENCE AS INQUIRY NS.K-4.3 – LIFE SCIENCE NS.5-8.3 – LIFE SCIENCE
Plant Multiplication	NS.K-4.1 – SCIENCE AS INQUIRY NS.5-8.1 – SCIENCE AS INQUIRY NS.K-4.3 – LIFE SCIENCE NS.5-8.3 – LIFE SCIENCE

Have fun! If students enjoy their time at the US Botanic Garden they are more likely to be interested in "digging deeper" into the lives of plants.

How Plants Work **Exhibit Introduction**

What's the Big Idea?

Student Objectives

Upon completing this Journal section, the student will be better able to:

1. Identify the 5 "Big Ideas" from the *How Plants Work* Exhibit at the US Botanic Garden.

Explore the Exhibit…

Guide students through the *How Plants Work* Exhibit to give them a general sense of the layout and major themes. *This should take approximately 10 minutes.*

[Insert East Gallery map with "How Plants Work" Big Idea sections highlighted – to be provided by Walter Sistrunk at USBG]

"Big Idea" topics to highlight include:

Big Idea 1: Are Plants Like Us?

Plants are like humans because both need energy to survive. However, plants are different because they create their own energy from the sun and can make their own food.
Highlight: The Plant Family Tree: Discuss how plants have evolved and are interrelated.

Big Idea 2: A Puzzle of Plant Parts

Plants have a number of parts (roots, stems, leaves, flowers, and seeds) that work together to harvest energy from the sun and utilize water and nutrients from the soil to ensure survival where they are planted.
Highlight: Over-sized sculpture *Scarlet magnifica*: Point out different plant parts represented on the sculpture (e.g. stems, roots, seeds, flowers, etc.).

Big Idea 3: The Green Machine

Both humans and plants are equipped with systems to ensure growth. Plants have the ability to make and use their own food using this "green machine."
Highlight: Over-sized sculpture *Electra botanica*: Use one or two of the buttons to light up *Electra* and introduce how photosynthesis occurs in plants.

Big Idea 4: Surviving Against the Odds

If humans are cold they put on sweaters to fight off a chill. Plants also employ adaptive strategies to adjust to their environment. Plants have evolved to look the way they do in order to thrive in local temperature, light, moisture, and soil type conditions.
Highlight: "Light" panel: boxed plant navigating towards light source: Show how plant adapted to the box environment and grew to reach a light source.

Big Idea 5: Plant Multiplication

To ensure species survival, plants, like humans, must reproduce and create offspring. Unlike humans, plants cannot travel around to find their mates. Instead plants depend on wind, water and other factors, such as animals, to disperse their seeds and spores.

Highlight: Live plant samples: Discuss the 4 major plant groups (ferns & mosses [reproduction with spores and not seeds], gymnosperms [cone-bearing plants], & angiosperms [flower-bearing plants]).

Become a Savvy Plant Sleuth!
Have students break up into five groups, one group per Big Idea. Students, guided by chaperones, should complete the Student Discovery Journal activity relating to their assigned Big Idea section. Upon returning to school, student groups can report back to the class what they learned as a result of their Student Discovery Journal activity.

Are Plants Like Us?
Do you really grow like a weed?

(Insert clip art of various kinds of plants, including jungle vines, orchids, ferns and cacti – to match Student Discovery Journal)

Student Objectives
Upon completing this Journal section, the student will be better able to:

1. Compare and contrast human and plant growth and development.
2. Use observational skills to develop hypotheses about plant growth and development.
3. Synthesize knowledge about plant growth and development.

Time Needed
45 minutes to 1 hour

Explore the Exhibit…
Let students explore the "Are Plants Like Us?" Exhibit area. (~5-10 minutes)

Discussion Prompt: How are humans and plants the same? How are they different? Have students find evidence in the Exhibit area to support their responses. (e.g. both grow, both need energy to function, plants make their own energy from the sun while humans get energy from eating plants and animals, etc.)

Become a Savvy Plant Sleuth!
Go into the Plant Exploration Room in the Conservatory. If students are not already in pairs, have them choose a partner.

[Insert USBG map with East Gallery & Plant Exploration Room highlighted]

Have students choose any plant in the Plant Exploration Room and compare it to their partner. They should complete the activity in the Student Discovery Journal (shown below). This activity is designed to familiarize students with ideas like: Both humans and plants grow, but the ways we attain and metabolize energy are different.

List 3 things both the plant and your partner can do:
Examples: grow, use water, eat, sunbathe, etc.

List 3 things the plant can do that your partner cannot do:
Examples: make his/her own food, produce oxygen, make flowers, make perfume, etc.

List 3 things your partner can do that the plant cannot do:
Examples: walk around, talk, put on a sweater if it gets cold, produce carbon dioxide, etc.

Time permitting, have students share one item from each list with the rest of their group.

Dig Deeper…
Tell students they will have a chance to take on the role of a botanist by exploring the plants of the United States Botanic Garden and developing hypotheses about plant light, water, and nutrient use. (If students are unfamiliar, define hypothesis: A tentative explanation for an observation, phenomenon, or scientific problem that can be tested by further investigation. This word is also defined in the Student Discovery Journal.) Students should use what they learned in the *How Plants Work* Exhibit, along with their own knowledge and observational skills, to create their hypotheses. Student responses do not need to match the provided examples or their peers' hypotheses. This activity is designed to challenge students to express logical thought and explore scientific inquiry.

[Insert USBG map with Jungle & World Deserts Room highlighted]

Take students up the Catwalk in the Jungle. Have them observe several epiphytes (non-parasitic plants that grow on top of, or are attached to, other plants - e.g. bromeliads & orchids) during their trek. Students should choose one epiphyte to draw in their Journal.

Discussion Prompt: How do these plants get light? How do they get water? How do they get nutrients? Focus student attention on the epiphyte root systems.

Have students develop a hypothesis about epiphyte light, water, or nutrient use. Samples include:

a. Epiphytes don't need soil to grow. They draw water and nutrients from the air. (e.g. Epiphytic orchids' aerial roots and leaves absorb nutrients and moisture brought by rain, mist, and other organisms.)
b. Epiphytes depend on other plants to get closer to sunlight, which epiphytes then use to create energy.

Take students to the World Deserts Room. Have them observe the different cacti. Students should choose one cactus to draw in their Journal.

Discussion Prompt: How do these plants get light? How do they get water? How do they get nutrients? Focus student attention on the cacti skin and stems.

Have students develop a hypothesis about cactus light, water, or nutrient use. Samples include:

a. Cacti can retain moisture in their tissues and remain succulent for long periods of time because of their waxy skin.
b. Cacti have roots that are close to the surface of the ground to help them absorb water and nutrients, taking advantage of even the smallest amounts of rainfall.

Tell students they can adjust these hypotheses as they progress through their Student Discovery Journals and learn more about plant life, adaptation, and survival.

What Did You Learn?
Return to the *How Plants Work* Exhibit.

[Insert USBG map with World Deserts Room & East Gallery highlighted]

Discussion Prompt: Consider the following statement: "Plants are like humans because both need energy to survive. However, plants are different because they create their own energy from the sun and can make their own food." Is this statement true or false? Why? Students should use information from their observations and the *How Plants Work* Exhibit to support their responses.

National Science Education Standards

- NS.K-4.1 – SCIENCE AS INQUIRY
  - As a result of activities in grades K-4, all students should develop abilities necessary to do scientific inquiry.
  - As a result of activities in grades K-4, all students should develop an understanding about scientific inquiry.
- NS.5-8.1 – SCIENCE AS INQUIRY
  - As a result of activities in grades 5-8, all students should develop abilities necessary to do scientific inquiry.
  - As a result of activities in grades 5-8, all students should develop an understanding about scientific inquiry.
- NS.K-4.3 – LIFE SCIENCE
  - As a result of activities in grades K-4, all students should develop an understanding of characteristics of organisms.
- NS.5-8.3 – LIFE SCIENCE
  - As a result of activities in grades 5-8, all students should develop an understanding of structure and function in living systems.

A Puzzle of Plant Parts

Why do plants have so many different parts?

(Insert around the corners of these pages drawings (or photographs) of interesting looking roots, stems, leaves, flowers, fruits, and seeds. Possible options include: a fig leaf next to a fern leaf next to at hawthorn branch and a root (carrot?) or one of each coming in from each corner of the pages – to match Student Discovery Journal)

Student Objectives

Upon completing this Journal section, the student will be better able to:

1. Explain the structure and function of different plant parts.
2. Use observational skills to theorize how the designs of distinct plant parts help plants adapt to and survive in their habitats.
3. Synthesize knowledge about the structure and function of different plant parts.

Time Needed

45 minutes to 1 hour

Explore the Exhibit…

Let students explore the "A Puzzle of Plant Parts" Exhibit area. (~5-10 minutes)

Discussion Prompt: Look at the sculpture *Scarlet magnifica*. What are the major plant parts highlighted? What are the jobs of each part? **Make sure that students notice the fruits and seeds station located near the door to the Plant Adaptations Room**

STEMS:

Have students examine *Scarlet's* stem.

Discussion Prompt: What do the Green and Blue cords represent? (In the Student Discovery Journal, students are asked to label the green and blue chords on a stem drawing from the *How Plants Work* Exhibit.) What would happen to a plant if it did not have a stem?

Become a Savvy Plant Sleuth!

Go into the Garden Court.

[Insert USBG map with East Gallery & Garden Court highlighted]

LEAVES:

Ask students to find and draw 2 different kinds of leaves displayed in the gallery space. The leaves they choose should be completely different in size, shape, and texture.

Discussion Prompt: What factors seem to influence the size of the plant's leaves? Facts for discussion:

- Plants found in the understory of tropical forests (i.e. in the shade of large trees) usually have large leaves to catch sunlight that falls through the forest canopy.

Even though they live in a tropical environment with a lot of light, there is tremendous competition for light because of the dense plant growth. As a result, leaves are usually large to serve as good "solar panels."

- Plants in the desert usually have very small or reduced leaf surfaces. They don't need to compete for light because there is a lot of light available and fewer plants to compete with. Instead, the adaptive pressure is to avoid water loss.

ROOTS:
Go to the Orchid Room.

[Insert USBG map with Garden Court & Orchid Room highlighted]

Ask students to find a plant that does not have underground roots. (If necessary, draw students' attention to the West African Rubber Tree [*Ficus vogelii*, Fig Family].) Students should sketch both the plant and its surrounding habitat in the space provided in their Student Discovery Journals.

Discussion Prompt: As students sketch, ask: Why do you think these plants are designed with roots above ground? What purpose do they serve? In which environment are they most likely to thrive? Facts for discussion:

- Some trees and other plants that live in environments with shallow or wet soils (e.g. some forests and mangrove swamps) have prop or stilt roots, which grow from main trunks to the soil or buttress roots (huge ridges at the base of trees). These give the plants extra stability and keep them from toppling.
- Epiphytic orchids grow on other plants. This is an adaptation to life in the tropical forest, where the climate is warm and moist; the air never freezes, and light is scarce below the canopy. These plants find a perch on other plants above ground level in order to find more favorable conditions, but they are not parasitic. These orchids' aerial roots and leaves absorb nutrients and moisture brought by rain, mist, and other organisms.

FLOWERS:
Have students examine the Orchid samples. Prompt students to draw their favorite in the space provided in the Student Discovery Journal.

Discussion Prompt: What was the reason for their flower choice? What is the purpose of a flower for a plant? Facts for discussion:

- Flowers advertise a plant to pollinators. Some use bright color, scent, or patterns to entice insects and birds to interact with the flower and increase chances for pollination.

Dig Deeper…
Return to the Garden Court. Through investigations of the Garden Court plants, students should complete the following chart found in their Student Discovery Journal. (Sample answers provided.)

1. Find a plant that humans depend on for something they drink. Which part of the plant is used in this drink?
   Plant: ___*coffee plant*___ Product: ___*coffee*___ Plant Part: ___*seed (berries)*___
   Other choices: Tea plant (tea made from leaves), Seville Orange Tree (orange juice made from fruit), Bergamot Orange (orange juice made from fruit)

2. Find and list below two plants with parts that are used to season and flavor foods and/or drinks. What part of that plant do you use?
   Plant: ___*Tarragon*___ Usable Part: ___*leaves*___
   Plant: ___*Cinnamon*___ Usable Part: ___*bark*___
   Other choices: Oranges (fruit), Sage (leaves), Allspice (berries), Vanilla (seeds)

3. Look at the large murals. (There are 6 murals along the north walls of the Garden Court.) Find a plant that is used to make a product that you didn't know came from plants. What part of the plant does this item come from?
   Plant: ___*cotton*___ Product: ___*t-shirt*___ Plant Part: ___*seed*___

What Did You Learn?
Return to the *How Plants Work* Exhibit.

Discussion Prompt: "Plants and animals are both living things but their parts function differently to allow them to cope with the challenges in their environments." Is this statement true or false? Why? Have students support their answers with evidence from the *How Plants Work* Exhibit and Conservatory explorations.

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  - As a result of activities in grades K-4, all students should develop an understanding about scientific inquiry.
- NS.5-8.1 – SCIENCE AS INQUIRY
  - As a result of activities in grades 5-8, all students should develop abilities necessary to do scientific inquiry.
  - As a result of activities in grades 5-8, all students should develop an understanding about scientific inquiry.
- NS.K-4.3 – LIFE SCIENCE
  - As a result of activities in grades K-4, all students should develop an understanding of characteristics of organisms.
  - As a result of activities in grades K-4, all students should develop an understanding of organisms and environments.
- NS.5-8.3 – LIFE SCIENCE
  - As a result of activities in grades 5-8, all students should develop an understanding of structure and function in living systems.
  - As a result of activities in grades 5-8, all students should develop an understanding of diversity and adaptations of organisms.

The Green Machine

How is a plant like a machine?

(Insert drawings or photographs viewing plant structures & cells from under a microscope – match to Student Discovery Journal)

Student Objectives

Upon completing this Journal section, the student will be better able to:

1. Explain how plants convert sunlight into energy.
2. Use observational skills and illustrations to theorize the roles of different green machine parts in the photosynthesis process.
3. Synthesize knowledge about how plants convert sunlight into energy.

Time Needed

45 minutes to 1 hour

Explore the Exhibit…

Let students explore the "Green Machine" Exhibit area. (~5 minutes)

Gather students around the plant sculpture *Electra botanica*. Have students take turns pushing the buttons to light up the different processes taking place inside the plant.

Discussion Prompt: What processes do the different colored lights represent?

Students should complete the following chart in their Student Discovery Journals:

Find the "Leaves and Stems" and "Roots" labels by *Electra botanica.* Then draw a line to connect the activity description with the light activity represented on the large sculpture. (Sculpture schematic located in Student Discovery Journal.)

Blue lights in tubes = Water movement (*water flow*)

Green solitary blinking lights = Chlorophyll molecules capture light energy and carry out photosynthesis (*energy flow*)

Red lights in tubes = Carbon dioxide bonds with remaining Hydrogen ions to form simple sugars energized by ATP (*energy flow*)

Orange solitary blinking lights = Sugars converted to starch (storage) and cellulose (building tissue) (*energy flow*)

Discussion Prompt: Tell students that machines are **systems** that take a number of components and use energy to create a product. Use the students' exploration of *Electra* to discuss the concept of SYSTEMS. Ask, how does this Green Machine work? Facts for Discussion:

- Green machine major inputs: SUN (light), carbon dioxide, water

- What are the major products: sugars (in the form of glucose- C6 H12 O6) that are stored as carbohydrates, oxygen

Have students look at the walls in the *How Plants Work* Exhibit and view the Electron Microscope photography. Find the cross section photos of the Christmas Rose Leaf and the Horsetail Stem. (The Christmas Rose Leaf is above the benches by the entrance to the Garden Court. The Horsetail Stem is along the outer wall behind the purple Plant Multiplication panels.) Focus on the different components of the picture, with regard to what green machine system elements are represented (e.g. chloroplasts, cellulose).

Discussion Prompt: What are these photos? What part of the plant is on display? What can these photos tell about plant energy production?

Become a Savvy Plant Sleuth!
Take students to the Jungle in the Conservatory.

[Insert USBG map with East Gallery & Jungle highlighted]

Using what they learned in the Green Machine portion of the *How Plants Work* Exhibit, have students find a plant they enjoy. Students should first draw the plant. Once their drawing is complete, prompt students to recall the Electron Microscope photography and draw the inside of their plant, essentially taking an imaginary X-ray of the plant. Students should label the plant systems like the Green Machine example *Electra* and point out the main components that enable the plant to run smoothly.

Discussion Prompt: Ask students to illustrate/list their plant's energy source. What fuels this **system**? (*Answer: The Sun*)

Students should draw a close up picture of one of their plant's leaves. Have students recall their examination of *Electra* and the Electron Microscope photography to list the leaf parts that are the sun's energy receivers. (*Sample answers: thylakoids, chloroplasts, etc.*)

Discussion Prompt: Have students think back to the *How Plants Work* Exhibit. Ask: What are the products of photosynthesis? Facts for discussion:
- The products of photosynthesis are oxygen and food for energy and growth.
- For less advanced students, focus more upon how plants MAKE their own food not necessarily HOW they do it.

Dig Deeper…
Return to the *How Plants Work* Exhibit.

Discussion Prompt: How is the way that plants create and use energy different from the ways that humans attain, utilize and produce energy? Items for discussion:
- Discuss how plants are capable of producing their own food and how animals – including people – are not.

- Make a connection for the students regarding man's dependence upon plants and a plant's Green Machine for man's survival. (e.g. Even if students say they don't like vegetables, there are probably a few that they do like and/or will eat. In addition, many of their favorite foods, like hamburgers or tacos, can be broken down into ingredients that can be traced back to plants.)
- Why is the landscape green? (Plants produce more than animals can consume, leaving green space. Green space is also a measure of how much life earth can support.) What are the implications of a green (or a brown) landscape? What other value do plants provide beyond primary consumption by animals?

What Did You Learn?
Both plants and humans contain a variety of systems to ensure growth.

Discussion Prompt: How do plants use their "green machines" to make and use their own food? What are the different plant parts? How do they work together to help the plant thrive and survive?

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- NS.5-8.1 – SCIENCE AS INQUIRY
  - As a result of activities in grades 5-8, all students should develop abilities necessary to do scientific inquiry.
  - As a result of activities in grades 5-8, all students should develop an understanding about scientific inquiry.
- NS.K-4.3 – LIFE SCIENCE
  - As a result of activities in grades K-4, all students should develop an understanding of characteristics of organisms.
- NS.5-8.3 – LIFE SCIENCE
  - As a result of activities in grades 5-8, all students should develop an understanding of structure and function in living systems.
  - As a result of activities in grades 5-8, all students should develop an understanding of regulation and behavior.

Surviving Against the Odds

How do plants adapt and survive?

(Insert a drawing or photograph of a cactus in one corner and a vine system in an opposing corner – match to Student Discovery Journal)

Student Objectives

Upon completing this Journal section, the student will be better able to:

1. List different ways plants adapt to their environment.
2. Use observational skills to evaluate plant adaptations for different environments and outcomes.
3. Synthesize knowledge about plant adaptations.

Time Needed

1 hour

Explore the Exhibit…

Let students explore the "Surviving Against the Odds" Exhibit area. (~5-10 minutes)

Discussion Prompt: Ask: Why do plants need adaptations? What are some examples of different plant adaptations? Facts for discussion:

- *Physical adaptations:* fluff on dandelions that can help seeds spread, deep roots that reach down for water, spikes on burdocks stick to fur or clothing (to aid the process of seed dispersal)
- *Growth patterns:* stems that reach toward the light, big leaves to catch the light
- *Physiological adaptations:* trees release compounds to heal wounds, etc.
- *Partnerships between plants and animals:* insects that pollinate flowers

Have students' list examples of each type of adaptation in their Student Discovery Journal.

Adaptation	**Plant Example**
Physical Adaptation	
Growth Pattern Adaptation	
Physiological Adaptation	
Plant-Animal Partnership Adaptation	

Discussion Prompt: Which adaptation do students find most interesting? Why?

Become a Savvy Plant Sleuth!

Take students on a Scavenger Hunt through the Conservatory.

Pre-Scavenger Hunt Discussion Prompt: "Plants only have so much energy so they need to make good use of it. Adaptations take energy to create, so each one of these characteristics has a specific function." Have students brainstorm one or two possible adaptations and their functions. (Possible adaptations include fragrance, color, or fleshy, edible fruit and berries.)

[Insert USBG Conservatory map]

Students then complete the Scavenger Hunt Chart located in their Student Discovery Journals:

Adaptive Trait	**Plant**	**Country of Origin**	**Why you chose it**
A plant that looks like it could stop herbivores from eating it.			
A plant with flowers that are arranged in clusters.			
A plant with leaves that appear to be chewed.			
A plant with aerial roots.			
Two different plants with leaves made to thrive in a very rainy environment.			
A plant that appears to depend upon another plant for survival.			
A plant that has characteristics to help protect it from the hot desert sun.			

Additional Information or Examples about each Adaptive Trait:

1. A plant that looks like it could stop herbivores from eating it.
    - Hawthorne branch, acacia tree, or cacti, which possess spines etc.
    - Suggested Locations at USBG: Plant Adaptations Room, Rare & Endangered Plant Room or World Deserts Room

2. A plant with flowers that are arranged in clusters. *Why might pollinators like this arrangement?*
    - Offers potential pollinators a large and more visible target.
    - Having so much nectar available in one place saves them time and energy.
    - Flowers clustered along a stem often open in sequence that holds pollinators' attention throughout the season.
    - Suggested Locations at USBG: Plant Exploration Room, Orchid Room or Jungle
3. A plant with leaves that appear to be chewed. *Why would a plant grow this way?*
    - To deter predators, some plants have leaves that already appear eaten.
    - Example: Window Leaf (vine) [aka Swiss Cheese Plant]
    - Suggested Locations at USBG: Jungle
4. A plant with aerial roots. *How these roots help the plant survive in its environment?*
    - Aerial roots are roots that form and remain above ground.
    - Generally help to stabilize the plant in addition to absorbing water and nutrients.
    - Can allow the plant to climb, increase absorption, and/or exchange nutrients & gases.
    - Examples: Epiphytes (Orchids), Mangrove Trees, Poison Ivy, Banyan Trees
    - Suggested Locations at USBG: Orchid Room or Jungle
5. Two different plants with leaves made to thrive in a very rainy environment.
    - Many plants in rainforests or jungle environments have elliptical leaves with elongated "drip tips" that shed excess water.
    - Channeled midribs that act as "gutters" for drainage.
    - Waxy cuticles that allow water to run off (like a freshly waxed car!).
    - Suggested Locations at USBG: Jungle or Garden Primeval
6. A plant that appears to depend upon another plant for survival.
    - Bromeliads live in the treetops of the rainforest
    - Vines use trees as support so that they can climb high into the canopy in search of sunlight.
    - Suggested Locations at USBG: Orchid Room or Jungle
7. A plant that has characteristics to help protect it from the hot desert sun.
    - Possess thick, juicy stems that can store water and spines to keep herbivores from accessing this water.
    - Often white, silver, or gray with hairs or velvety fuzz – act as light reflectors.
    - Deep roots
    - Thorns
    - Reduced leaf surface – often very lacy – to prevent water loss (transpiration).
    - Suggested Locations at USBG: Rare & Endangered Plant Room or World Deserts Room

The Scavenger Hunt will conclude in a room with cacti. If not already there, walk through the World Deserts Room and the Garden Primeval to return to the *How Plants Work* Exhibit.

[Insert USBG map with World Deserts Room, Garden Primeval, & East Gallery highlighted]

Discussion Prompt: What are the major differences between plants growing in the World Deserts Room and the Garden Primeval? Facts for discussion:

- Some plants have thicker, waxy leaves; some plants have thorns.
- Aloe and jade have waxy coatings that prevent water loss (transpiration).
- Many desert plants have small leaves or spines in place of leaves.
- Some cacti are covered with what appear to be white hairs, which help reflect the hot desert sun. Thorns help to deter animal predators that are seeking the water stored in the spongy leaves.
- Ferns have large leaves to help capture as much light as possible from their shady habitats.
- Plants designed to live in hot, dry exposed climates vs. hot, wet, shady climates.

Dig Deeper…

Have students reflect on their own experiences adapting to their environment. How do they cope with challenges in their environments?

Chart Activity: What do you do if it is…

- Wet? (*Sample Answers: umbrella, rain coat, bathing suit*)
- Windy? (*Sample Answers: windbreaker, scarf*)
- Hot? (*Sample Answers: go swimming, sit in the shade*)
- Cold? (*Sample Answers: bundle up!, go inside, make a fire*)

Have students repeat the process considering the life of a plant.

Chart Activity: What does a plant do if it is…

- Wet? (*Sample Answers: leaves designed for water drainage*)
- Windy? (*Sample Answers: pollinators that are blown around*)
- Hot? (*Sample Answers: thick waxy skin to conserve water*)
- Cold? (*Sample Answers: losing leaves in winter*)

Challenge students to create an adaptation for:

- Themselves and/or a friend
- A plant that lives in their schoolyard

Have students choose their favorite of the three adaptations they just created. Ask them to draw it, explain why it is important, and how it works.

What Did You Learn?
Discussion Prompt: Why do plants need adaptations? What are some examples of plant adaptations seen at the US Botanic Garden Conservatory? Could plants survive without certain adaptations? Why or why not?

National Science Education Standards

- NS.K-4.1 – SCIENCE AS INQUIRY
  - As a result of activities in grades K-4, all students should develop abilities necessary to do scientific inquiry.
  - As a result of activities in grades K-4, all students should develop an understanding about scientific inquiry.
- NS.5-8.1 – SCIENCE AS INQUIRY
  - As a result of activities in grades 5-8, all students should develop abilities necessary to do scientific inquiry.
  - As a result of activities in grades 5-8, all students should develop an understanding about scientific inquiry.
- NS.K-4.3 – LIFE SCIENCE
  - As a result of activities in grades K-4, all students should develop an understanding of characteristics of organisms.
  - As a result of activities in grades K-4, all students should develop an understanding of organisms and environments.
- NS.5-8.3 – LIFE SCIENCE
  - As a result of activities in grades 5-8, all students should develop an understanding of structure and function in living systems.
  - As a result of activities in grades 5-8, all students should develop an understanding of populations and ecosystems.
  - As a result of activities in grades 5-8, all students should develop an understanding of diversity and adaptations of organisms.

Plant Multiplication

How do plants reproduce?

(Insert photo or drawing of a flower, the underside of a fern leaf to show spores, and/or a cone bearing plant – match to Student Discovery Journal)

Student Objectives

Upon completing this Journal section, the student will be better able to:

1. Explain the reproductive strategies of the 4 major plant groups.
2. Use observational skills to evaluate reproductive strategies of various plant groups.
3. Synthesize knowledge of plant reproductive strategies.

Exhibit Synopsis: Plants can be divided into 4 major groups depending upon their reproduction strategy. The 4 major plant groups are:

- ferns and mosses (which both reproduce by spores not seeds)
- gymnosperms (cone-bearing plants)
- angiosperms (flower-bearing plants)

The reproduction strategies employed by these different plant groups have changed throughout time and are good indicators of how plants have adapted to environmental stresses that lead to evolutionary change.

Explore the Exhibit…

Let students explore the "Plant Multiplication" Exhibit area. (~5-10 minutes)

Have students examine each section of the "Plant Multiplication" Exhibit area and become an expert on 1 plant group that interests them. Students should draw an example from their plant group choice and list a few of its unique reproductive characteristics.

OR

Divide students into groups or pairs. Assign each group or pair one of the 4 major plant groups. Ask students to become experts on their designated plant group. Have students draw 1 or more examples from their plant group and list its unique reproductive characteristics.

Take a moment to have the students share their findings. Depending on time constraints, teachers/chaperones may only want to have students show their drawing and how it explains the plant group's reproduction strategy.

Become a Savvy Plant Sleuth!

Take students into the Medicinal Plants Room

[Insert USBG map with East Gallery & Medicinal Plants Room highlighted]

Have them find a flower in the process of turning into a fruit. (Seek out the pepper plants. If it isn't possible to find a flower in the process of becoming a fruit, have students find a plant with fruit and talk about the process of going from flower to fruit. Look closely at the fruit to see any evidence of the flower [e.g. the calyx of an apple].) Students should sketch their selection.

Discussion Prompt: What happens to this plant before and after this stage? Facts for discussion:

- The flower is fertilized and then produces a seed and a fruit. Look carefully.
- After a flower is pollinated the job of the petals and sepals is done and the plant allows these floral parts to die and fall off.
- On many fruits, you can see the dried remains of the sepals. (e.g. an apple – close examination of an apple should reveal the dried sepals at the "bottom" of the fruit)
- The resulting fruit (e.g. apple) may play an important role in seed dispersal depending upon what kind of plant it is.

Walk over to the Garden Primeval.

[Insert USBG map with Medicinal Plant Room & Garden Primeval highlighted]

Allow students to explore the various plants.

Discussion Prompt: Which plant group is represented in this section of the Conservatory? (*Answer: Ferns & Mosses*)

Have students examine ferns for sori (brown dots on the underside of the fern leaves). See if any students can find moss with sporophytes.

Discussion Prompt: What is the role of sori in the reproductive strategy in ferns? Did anyone find moss with a sporophyte? What is the purpose of the sporophyte? If no mosses exist with sporophytes, ask: Why do you think no moss in the Garden Primeval have sporophytes? Facts for discussion:

- A fern sporophyte includes the frond, a stem, and exterior roots that grow down the stem. The frond first appears as a 'fiddlehead' and then unfurls to reveal the leaf blades. When the blades emerge, small, circular, rust-colored patches may be found on the underside of some leaves. These are clusters of sori (singular: sorus), which release spores into the wind for dispersal. Spores that find homes in shady, wet/moist locations may develop into gametophytes (sometimes called "Irish valentines" because of their green, heart-shaped appearance).While in this stage, the gametophyte produces both sperm and eggs, which together produce a young sporophyte and the process begins again.
  (All fern information taken from the book *Introductory Plant Biology* (eight edition) by Kingsley R. Stern)
- Moss reproduction is similar to fern reproduction. Antherozoids (sperm equivalent) are produced in tiny sacs. On their release from the sacs, the antherozoids must then swim through surface water to fertilize nearby egg cells.

This need for surface water for successful reproduction ties mosses to habitats where wet conditions occur at least occasionally. Egg cell fertilization results in the development of a new stage in the moss life cycle. This is the sporophyte, consisting of a stalked capsule, whose base remains attached to the parent moss tissue. Sporophytes are reliant on the parent plant for nutrients and water.

- Spores are produced within the uplifted capsules of the moss sporophyte and then shed, depending on the amount of moisture in the air. When there is enough moisture in the air, a gap in the tip of the sporophyte opens and the wind shakes the spores out of the capsule. When the spores reach a suitable environment and grow, they will eventually produce a new moss plant.
  (All moss information retrieved from the Web site http://www.countrysideinfo.co.uk/moss_article/page1.htm on 2/28/08)

If they haven't already seen it, have students find the dinosaur.

Discussion Prompt: Why is there a dinosaur here? Can you see dinosaurs alive today? Can you see ferns and mosses? How did ferns and mosses survive while the dinosaurs became extinct? (Relate fern and moss survival to their successful reproductive strategy vs. the unsuccessful reproductive strategy used by dinosaurs – e.g. gestation, growth & development, environmental conditions and adaptations, etc.)

Dig Deeper…
Return to the *How Plants Work* Exhibit.

[Insert USBG map with Garden Primeval & East Gallery highlighted]

Visit the large Plant Family Tree graphic found facing the doors to the Garden Court. Observe how different reproductive strategies help determine where plants are located on the tree.

Discussion Prompt: Which plant group is the largest? How does your knowledge of plant reproduction strategies help you determine why one plant group family might be larger than another?

What Did You Learn?
Discussion Prompt: Plants, like animals, must reproduce and create offspring to ensure species survival. However, unlike animals, plants cannot travel around to find mates. What reproductive strategies do plants use for survival? Which do you think is the most effective? Why?

National Science Education Standards

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  - As a result of activities in grades K-4, all students should develop abilities necessary to do scientific inquiry.
  - As a result of activities in grades K-4, all students should develop an understanding about scientific inquiry.

- NS.5-8.1 – SCIENCE AS INQUIRY
  - As a result of activities in grades 5-8, all students should develop abilities necessary to do scientific inquiry.
  - As a result of activities in grades 5-8, all students should develop an understanding about scientific inquiry.
- NS.K-4.3 – LIFE SCIENCE
  - As a result of activities in grades K-4, all students should develop an understanding of characteristics of organisms.
  - As a result of activities in grades K-4, all students should develop an understanding of the life cycles of organisms.
  - As a result of activities in grades K-4, all students should develop an understanding of organisms and environments.
- NS.5-8.3 – LIFE SCIENCE
  - As a result of activities in grades 5-8, all students should develop an understanding of structure and function in living systems.
  - As a result of activities in grades 5-8, all students should develop an understanding of reproduction and heredity.
  - As a result of activities in grades 5-8, all students should develop an understanding of populations and ecosystems.
  - As a result of activities in grades 5-8, all students should develop an understanding of diversity and adaptations of organisms.

Teacher's Edition of the Student Discovery Journal
Review: What Have You Learned?

Concluding the trip: What have students learned today? What are the important take home messages? Consider what to expand upon back in the classroom.

Big Idea 1: Are Plants Like Us?
Plants are like humans because both need energy to survive. However, plants are different because they create their own energy from the sun and can make their own food!

To continue exploring this topic, refer to the following Post-Visit Lessons, located on the United States Botanic Garden Web site: Pitching Plants & Rewards of a Green Scene.

Big Idea 2: A Puzzle of Plant Parts
Like humans, plants have a number of parts (roots, stems, leaves, flowers, and seeds) that work together to harvest energy from the sun and utilize water and nutrients from the soil to ensure survival where they are planted.

To continue exploring this topic, refer to the following Post-Visit Lessons, located on the United States Botanic Garden Web site: Plant Parts Feast, Invent a Plant, Tread on Me! Grasses Measure Up, Catch Them in the Act! How Neighborhood Plants Get By, Pursuing Pollination Partners, Growing Tips, Flowers Up Close, Fruit for Thought I: Getting to the Core & Fruit for Thought II: Flower to Fruit.

Big Idea 3: The Green Machine
Both humans and plants are equipped with systems to ensure growth. Plants have the ability to make and use their own food using this "green machine."

To continue exploring this topic, refer to the following Post-Visit Lessons, located on the United States Botanic Garden Web site: Tread on Me! Grasses Measure Up & Growing Tips.

Big Idea 4: Surviving Against the Odds
If humans are cold they put on sweaters to fight off a chill. Plants also employ adaptive strategies to adjust to their environment. Plants have evolved to look the way they do in order to thrive in local temperature, light, moisture, and soil type conditions.

To continue exploring this topic, refer to the following Post-Visit Lessons, located on the United States Botanic Garden Web site: Invent a Plant, Tread on Me! Grasses Measure Up, Catch the in the Act! How Neighborhood Plants Get By & Pursuing Pollination Partners.

Big Idea 5: Plant Multiplication
To ensure species survival, plants, like humans, must reproduce and create offspring. Unlike humans, plants cannot travel around to find their mates. Instead plants depend on wind, water and other factors, such as animals, to disperse their pollen, seeds, and spores.

To continue exploring this topic, refer to the following Post-Visit Lessons, located on the United States Botanic Garden Web site: Pursuing Pollination Partners, Flowers Up Close, Fruit for Thought I: Getting to the Core, Fruit for Thought II: Flower to Fruit & Plant Elders: Seedless But Savvy.

(Insert botanical-themed graphics that were used on the introductory page of the teacher's edition of this journal)